Lecture 4 : The basics of ship hull form design

A ship's hull is a very complicated 3D shape. Since it is difficult to express a ship’s shape by a single equation Naval Architects place great emphasis on the graphical description of hull forms by line drawings. In the past this work was done by hand. Today high-speed digital computers assist and Computer Aided Design (CAD) packages can assist with hull form design (both line drawings and hull surface construction). However, they are neither substitutes for imagination and sound judgment. Hull line drawings consist of the intersection of the hull with a series of planes. The planes are equally spaced in each of the three dimensions. Sets of planes are mutually perpendicular or orthogonal, i.e. planes in one dimension are perpendicular to planes in the other two dimensions. The points of intersection of these orthogonal planes with the hull result in a series of lines that are projected onto a single plane located on the bow, deck, or side shell of the ship. This results in three separate projections, or views, called the ‘‘*Body plan*’’, the ‘‘*Half-Breadth plan*’’, and the ‘‘*Sheer plan*’’, respectively. Figures 4.1, 4.2 display the creation of these views in 3D and 2D respectively. Drawings display idealizations of a classic mono-hull design (i.e. a design that is symmetric about the longitudinal plane).

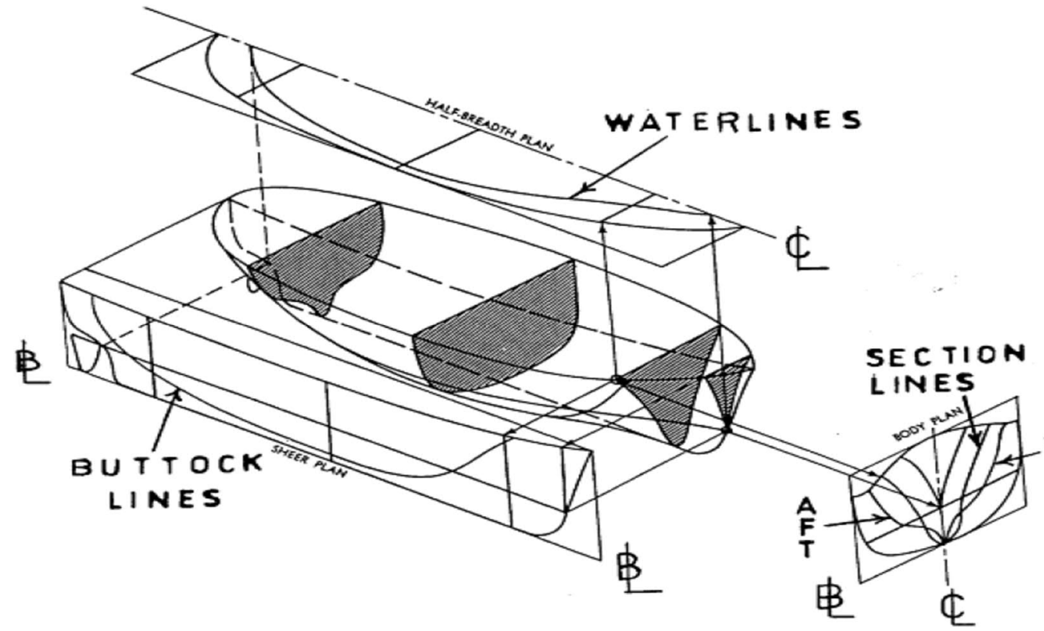


Figure 4.1 3D projection of lines onto three orthogonal planes

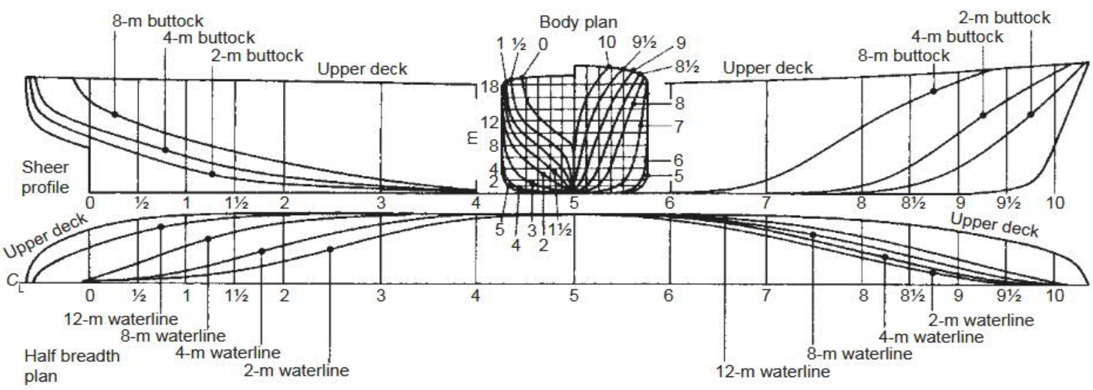


Figure 4.2 2D projection of the lines plan of a mono-hull. (Tupper, 2013)

The intersection of the horizontal planes with the hull shape results in lines called **waterlines** and their view in the hull lines drawing is known as the **half-breadth plan** as only half of the ship is drawn. Each waterline shows the true shape of the hull from the top view for some elevation above the base plane (or keel) which allows this line to serve as a pattern for the construction of the ship's framing. The lines formed by the intersection of the planes parallel to the middle line longitudinal plane are called **buttocks** and the line of intersection with the middle line plane is called **profile**. Each buttock line shows the true shape of the hull from the side view for some distance from the centerline of the ship. This allows them to serve as a pattern for the construction of the ship's longitudinal framing.The overall side view of the ship is known as the **sheer profile**. Finally, the lines of the intersection with transverse planes are called stations and are represented on the **body plan** view. Stations are odd in number and therefore evenly/equally spaced (i.e. 11, 21, 31, or 41). The plane that runs from bow to stern directly through the center of the ship and parallel to the sides of the imaginary box is called the **centerline plane**. Each sectional line shows the true shape of the hull from the front view for some longitudinal position on the ship which allows this line to serve as a pattern for the construction of the ship's transverse framing A series of planes parallel to one side of the centerline plane are imagined at regular intervals from the centerline.

1. Determination of the hull shape

In Lectures 2,3 we introduced the basics of ship hull form coefficients and different methods for determining a ship's main dimensions. Figure 4.2 outlines a practical process of determining the hull form :

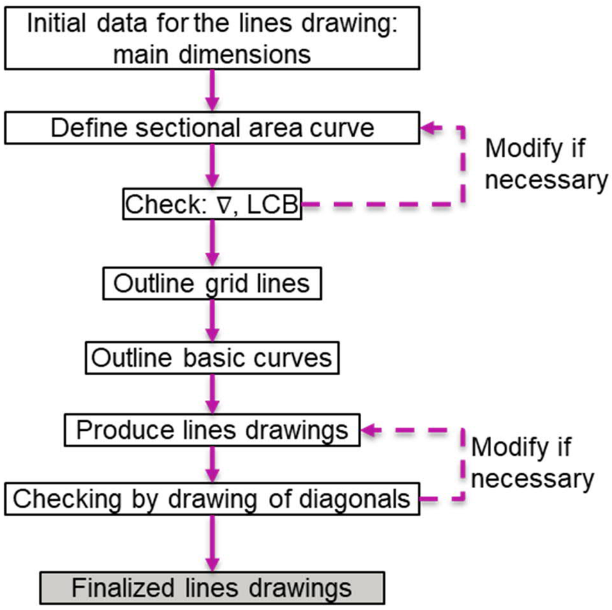


Figure 4.2 Practical method for hull form design

Hull form design influences ship performance. It therefore affects various design decisions related to : (a) ship resistance and propulsion ; (b) intact and damage stability ; (c) seakeeping performance in waves; (d) maneuvering capabilities; (e) volume of holds and cargo; (g) simplicity, ease and thus cost of construction. Detailed outlined of concepts reflecting the later go beyond the purpose of this course. However, the following sub - sections outline items that if considered appropriately can help with the practical hull lines generation outlined in Figure 4.2.

Sectional Area Curve. When the ship main dimensions (L,B,T), and the displacement are known, the displacement's longitudinal distribution can be determined by using the sectional area curve (Figure 4.3). Longitudinal positions on this curve represent sectional area values. The integrated area under the sectional area curve gives the displaced volume and the center of this area gives the center of volume of the ship (the longitudinal center of buoyancy LCB). The curve is extended over the ship's length which is divided into three lengths namely : (a) the entrance length, (b) the length of run, and (c) the length of the parallel middle body. The Parallel body length L_P corresponds to the part of ship's length for which we have constant sectional area. The length of entrance L_E and the length of run L_R correspond to the fore and the aft of the vessel's sectional area curve.

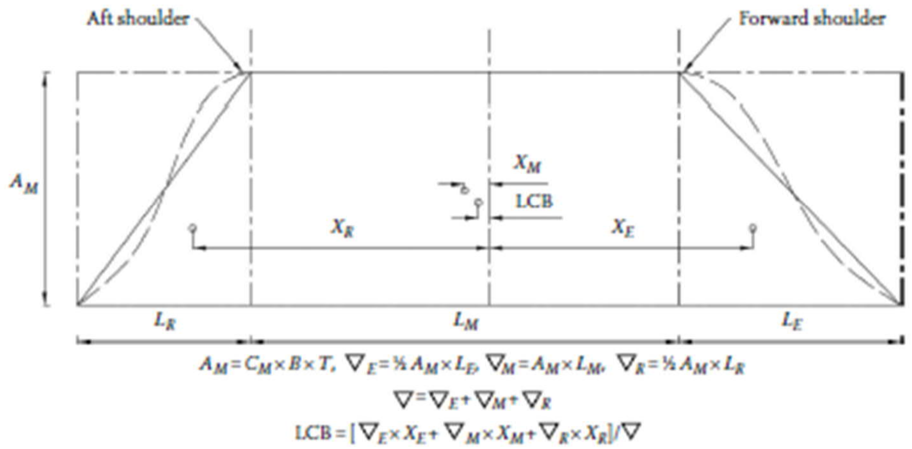


Figure 4.3 Geometric generation of the sectional area curve (Misra,2016)

Longitudinal Center of Buoyancy (LCB). To decide on the longitudinal center of buoyancy in early stages of design, there are some recommended optimal values derived from systematic experiments and numerical investigations. A graph for the optimum LCB as a function of the block coefficient and the sectional form type by Danckwardt is shown in (Figure 4.4). Generally, the LCB position is around the midship and tends toward the fore part or the stern depending on Froude number (F_n), and hence the block coefficient (C_B).

Length of Parallel Middle-body. As the length of the parallel middle-body may increase the mid-ship region outlined by the sectional area it may in turn lead to increase in the value of the prismatic coefficient and hence the ship's wave resistance. For low speed ships, the wave resistance part is not significant and consequently the effect of increasing the size of the parallel mid - ship body length is not momentous. From a construction perspective, the parallel mid - ship body is simple to construct because of the identical frames and structural elements used. Some recommended values for the length of parallel middle body are shown in (Table 3.1) and (Figure 5).

Length of entrance and length of run determine the forward and the abaft ship shoulder. The length of entrance(L_E) selection attempts to minimize the generated bow waves. Hence, wave resistance. The length of run (L_R) is selected should be selected in a way that we can minimize resistance. The aim is to avoid a very sharp aft shoulder which causes flow separation and increases in resistance. Figure 4.6 shows some recommended values of L_E, L_P and their relative position with respect to amidships versus the ship's prismatic coefficient (C_p).

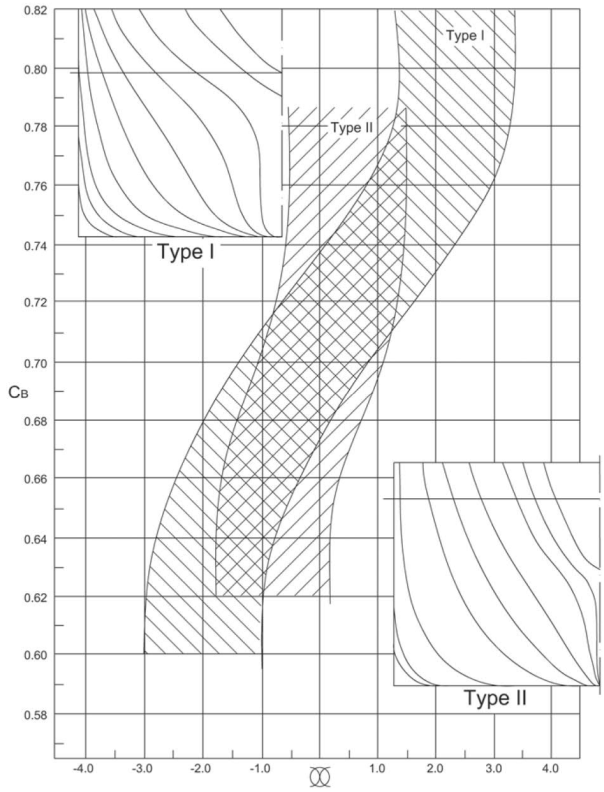


Figure 4.4 LCB as a function of C_B and hull form type (Papanikolaou, 2014)

Statistical Data	
Slow cargo ships	L_P = 0–0.10 L
Tankers and bulk carriers	= 0.30–0.40 L
Coasters	= 0.10–0.15 L
Other ships	without a parallel body

Table 3.1 Statistical data for recommended parallel middle-body (Papanikolaou, 2014)

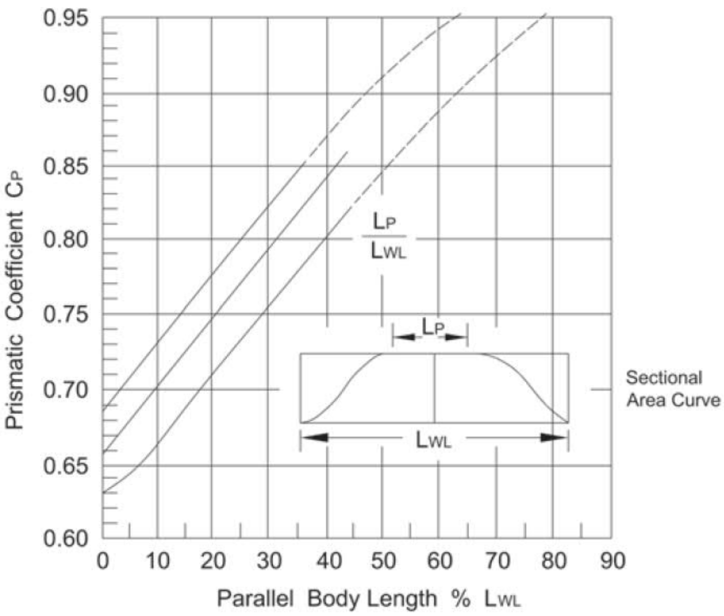


Figure 4.5 Parallel body length vs. prismatic coefficient (Papanikolaou, 2014)

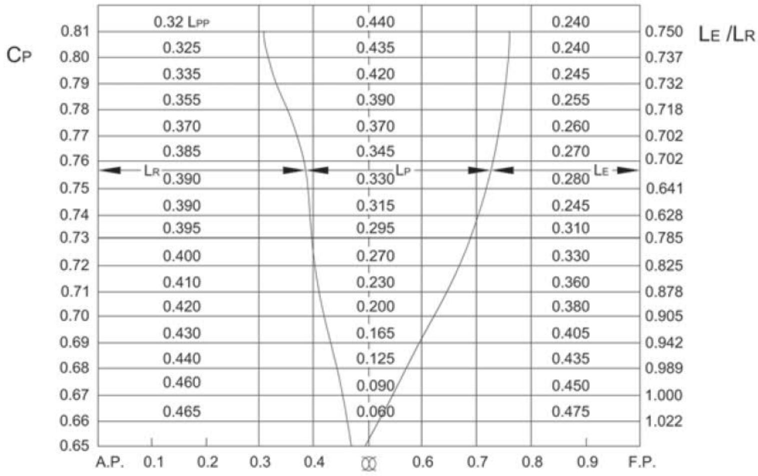


Figure 4.6 Length of entrance (L_E), length of run (L_R) and parallel middle body length versus prismatic coefficient (C_p) (Papanikolaou, 2014)

2. Ship sections

Common types of sections used in the field of Naval Architecture (see Figure 4.7) are : (a) U-type; (b) V-type ; (c) rectangular with round bilge (commonly for midship sections); (d) circular type (nearly constant radius for sailing yachts); (e) hard chine (single or double chines); (f) Bulbous type (commonly for bow and stern regions).

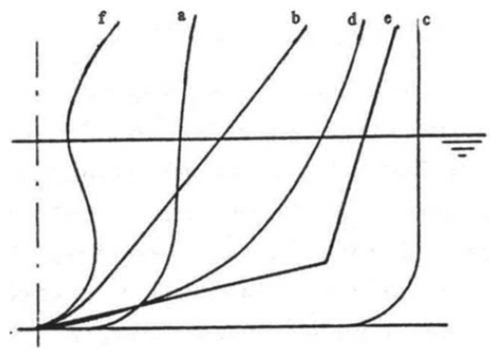
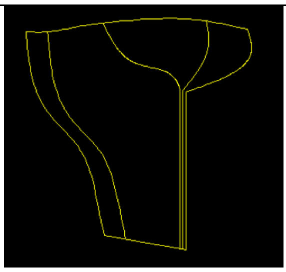


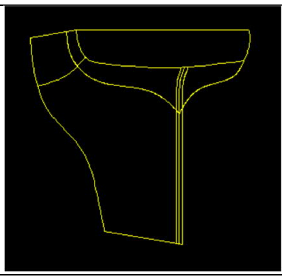
Figure 4.6 Different types of sections (Papanikolaou, 2014)

The **midship section** is the most relevant section for preliminary ship design and depends on the ship type. A rectangular mid - ship section is commonly used for cargo ships and a larger bilge can be used for fast ships. On the other hand, hard chine cross sections are usually used for High Speed Crafts (HSC). The midship area A_m , B, T and C_M are defined before the definition of a mid-ship section. So, the only variables of configuration are the bilge radius and the bottom deadrise. The relationship of bow and stern sections with the midship section, bow and stern shape requirements and the type of ship depends on the types of sections used. For example, if the midship section is full, then U or V type sections may represent the connection between the midship region and the stern or bow regions. Conversely, if the midship section is of a V-type (e.g. for a catamaran ship or another HSC), the connection should be only a V type in the bow and the stern. A ship that has a bulbous bow and/or a transom stern affects the selection of the fore and aft most neighboring sections. A transom stern requires relatively wide sections in way of the stern while the bulbous bow is based on relatively streamlined sections (see Figure 4.7). Operational requirements associated with a specific ship type may also affect the bow and stern forms. For example, ferries need a large deck area, so a V-type section is preferable. In bulk carriers and tankers, as the demand of having a large deck area is not important, the

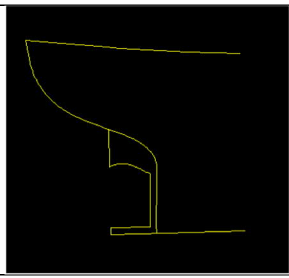
U section is preferable to allow the best use of enclosed spaces for cargo. It is noted that the selection of hull section type may also influence intact / damage stability and seakeeping performance and strength. However, these items are more deterministic and shall be discussed later on in the course and throughout the academic year.



(a) elliptical stern

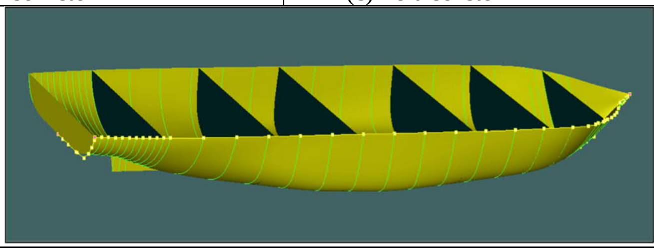


(b) transom stern

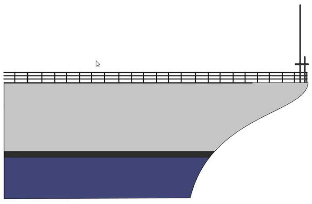


(c) cruiser stern

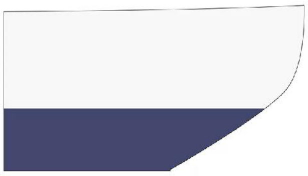
(d) Queen Mary II Constanzi stern



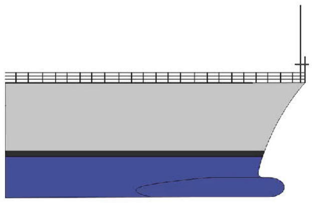
(e) CAD model of a hull form with fine stern



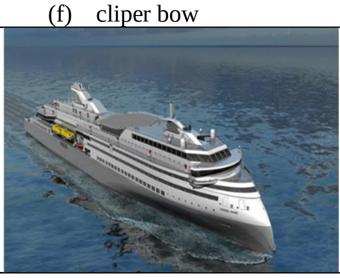
(f) cliper bow



(g) spoon bow

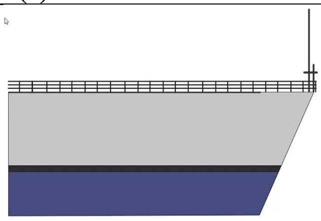


(h) bulbous bow



(i) X bow

(j) plump bow



(k) raked bow

Fig. 4.7 Different types of ship bow and stern idealisations (Image credit : https://www.marineinsight.com)

3. Questions

1. Choose the suitable midship section type for: container ship, sailing yacht, passenger ferry.
2. Draw a sketch for the sectional are curve of a bulk carrier C_P=0.8 and L_{PP}=150m. Calculate L_P, L_R and L_E .
3. Discuss the factors affected by the choice of the length of the parallel middle body, the length of run, and the length of entrance.
4. Discuss and provide examples on the relationship of ship's sections in different regions along its length.
5. What are the main variables when selecting a midship section of your ship?

6. The hull shape is traditionally described with a lines drawing. List and sketch the various items in a lines drawing and explain, what is the influence of the hydrodynamic factors on the optimal volume distribution of the hull.
7. Present a reflection on the process which you have used to define the hull form of your concept. Which factors affecting the hull form have you taken into account or you should have taken into and how? Justify your answers. Include the ship type of your concept in the answer.